The Portlandian strata of the Bas Boulonnais, France

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TOWNSON, W. G. & W. A. WIMBLEDON. 1979. The Portlandian strata of the Bas Boulonnais, France. Proc. Geol. Ass. 90 (2), 81–91. The Marine Portlandian strata in the Bas Boulonnais are c. 20 m thick, comprising the argillaceous glauconitic Assises de Croi overlain by the calcareous quartzose of the Gres des Oies. These are succeeded by a thin ‘Purbeckien’ algal limestone, the Calcaire des Oies (1 m), overlain by ‘Wealdien’ clays and sands (10–20 m?). The Kimmeridgian/Portlandian boundary (sensu anglico) lies within the basal few metres of the Assises de Croi and not at the Tour de Croi Nodule Bed as previously thought. The lower four Portlandian ammonite zones (Albani to Kerberus) are now proven to be present up to the Middle Gres des Oies, enabling correlation with England. The ‘Purbeckien’ limestone and ‘Wealdien’ clays are interpreted as non-marine Portlandian deposits and the ‘Wealdien’ sands as Lower Cretaceous in age. The Portlandian strata comprise an overall regressive sequence deposited in environments ranging from middle neritic to lacustrine.

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1. INTRODUCTION

The best exposed outcrops of Portlandian strata in southern England and northern France are the coastal sections of Dorset (type area) and the Bas Boulonnais, some 250 km due east. In between these two areas only limited borehole data exists. The Bas Boulonnais outcrop has been studied for many years and since the pioneer work of Fitton (1836) and d’Orbigny (1842–51, 1849–52, 1850–52) at least thirty papers have been published on various aspects of the succession. This contribution provides modern detailed lithological descriptions, a compilation of recorded fauna, a discussion of the ammonite stratigraphy, approximate correlations with the Portlandian of Dorset and an interpretation of the depositional history.

The English use of the terms Kimmeridgian and Portlandian unfortunately differs from that on the Continent. The ‘Portlandian’ of d’Orbigny (1850–52) included the Upper Kimmeridge Clay and the Portland Group of England, i.e. it commenced at the base of the late Kimmeridgian zone of Pectinatites elegans, whereas the Portlandian of the English (used herein) commences later, at the base of the zone of Progalbanites albani (for details see Cope 1967, Wimbledon 1974, and Wimbledon & Cope 1978). The Portlandian outcrop in the Bas Boulonnais covers an area of about 20 sq. km and the maximum thickness of the marine facies is approximately 20 m; this is thinner than the type section in Dorset (Townson 1975, Melville in press) or the sequence in the Vale of Wardour (Wimbledon 1976), but thicker than in the sections of the South Midlands (Wimbledon & Cope 1978).

2. LITHOSTRATIGRAPHY

The sequence which has long been regarded as equivalent to the ‘Portland Beds’ or Portland Group of Dorset (Townson 1971, 1975) was divided for 100 years into a lower ‘Marne (or Argiles) à Perna bouchardi et Ostrea expansa’ and an upper ‘Grès (or Couches) à Trigonia gibbosa’. They were renamed by Ager & Wallace (1966a) as the Assises de Croi overlain by the Grès des Oies (see Table 1). The base of this sequence is conveniently put at a condensed horizon, the Tour de Croi Nodule Bed (Table 1) which has hitherto been regarded as equivalent to the Rotunda Nodule Bed of Dorset and the Upper Lydite Bed of the South Midlands (for references see Ager & Wallace 1966a and Table 1). The Tour de Croi Nodule Bed rests on what was known as the ‘Argiles à Exogyra dubiensis’ of the Kimmeridge Clay, renamed (Ager & Wallace 1966a) as the Argiles de Wimereux. The
Fig. 1. Locality map for the Portlandian of the Bas Boulonnais, France.

Interbedded with sandy clays. The following descriptions are based on field observations and petrographic studies.

(a) Lower Assises de Croi (2-80–2-85 m; Fig. 2)

The basal bed, the Tour de Croi Nodule Bed (Table 1), is exposed at the foot of the cliff just north of Pointe de la Creche. It consists of a phosphatised concentration (0·15 m) of vertebrate fragments, bivalves, ammonites, gastropods, brachiopods, echinoids, belemnites and indeterminate phosphatic pebbles up to 20 mm across, see Part 3b(i). The clay matrix contains lignite, indigenous bivalves (Part 3b(i)) and ammonites, plus granules of quartz, quartzite and chert (lydite). Above this lies O· 2 m of slightly calcareous and glauconitic clay which contains *Rhynchonella* and lenses of *Exogyra* in its upper part. This is capped by a nodular limestone (0·15-0·2 m) composed of microsparite with <1 per cent quartz and glauconite, but with occasionallydite grains. The overlying O· 7 m consists of laminated calcareous silty sandy clay (vf-f quartz sand) with poorly preserved ammonites.

(b) Middle Assises de Croi (4·6–4·7 m; Fig. 2)

This sequence consists of alternations of 0·2–0·5 m
The latter are nodular lime mudstones which contain up to 1 per cent glauconite, common Exogyra, Astarte, echinoids and limestone nodules which appear to be altered large Thalassinoides. Above is 0·8-0·9 m of hard nodular limestone with scattered bivalve fragments and <1 per cent f-m quartz and glauconite. The overlying 1·5 m consists of three thin nodular limestones similar to that below, separated by calcareous silty clay with some f-m quartz and <1 per cent glauconite.

The sequence is characterised by the relatively high proportion of limestones and the incoming of large Thalassinoides.

(d) Lower Grés des Oies (2·5-2·85 m; Fig. 2)

The separation of these beds from the Middle Grés des Oies is arbitrary and made to correspond with the French division between lower beds with common 'Cardium pellati' (= Protocardia dissimilis) and higher beds with common Ampullospira ceres (Table 1), the sediment, however, is essentially the same throughout. The beds consist of soft v-f quartz sands with <5 per cent clay and carbonate, and <1 per cent glauconite. Thin cemented horizons are present (0·1-0·3 m) composed of v. fine quartz sand (80 per cent) with shells and shell fragments of bivalves and gastropods (<1 per cent glauconite) in a microsparite cement. The lower 0·7 m in places is a mixture of loose sand with sandstone nodules formed by diagenetic modification of large Thalassinoides.

The distinctive features of the Lower Grés des Oies are the dominance of fine-grained well-sorted sand and the presence of Protocardia.

(e) Middle Grés des Oies (0·3-5·5 m; Fig. 2)

These beds are composed of up to 80 per cent well-sorted v. fine quartz sand with only a small amount of clay, <1 per cent glauconite, micrite pellets (up to 1 mm), shells and fragments of bivalves and gastropods. A shelly cemented horizon (0·3 m) occurs in the middle, composed of microsparite with a variable amount of v. fine sand and no glauconite. The soft sands are bioturbated but at three localities some cross-bedding is discernable with foresets dipping northwards. The variation is thickness, and in places absence, of these beds is due to down-cutting by the Upper Grés des Oies.

The distinctive features of the Middle Grés des Oies are the very fine sand, the common Ampullospira and the preservation of some cross-bedding.

(f) Upper Grés des Oies (1·5-5+ m; Figs. 2 & 3)

The base of these beds is a hard shelly sandstone (0·1-0·2 m) composed almost entirely of v. fine quartz sand with a ferroan microspar cement. The bed is a 'hard-ground' with its upper surface bored by Lithophaga and encrusted with serpulids and oysters.
Moulds of aragonitic bivalves are either filled with the overlying sediment or remain empty. Considerable variation occurs above this hard ground, described as follows:

(i) North of Wimereux

At Pointe aux Oies the hard-ground rests on 2.0–2.5 m Middle Grès des Oies and can be traced southwards for about 1 km, maintaining approximately the same level. However, at Pointe de la Rochette in a distance of 100 m it cuts down through the Middle Grès des Dies to rest on the basal 1.5 m of the Lower Grès des Oies (Fig. 3). This bored horizon also occurs at the next exposure, about 1 km south of Wimereux, where it rests on 3.0 m of Middle Grès des Oies. The downcutting at Pointe de la Rochette is thus a local phenomenon (Fig. 3).

At Pointe aux Oies the bored surface is covered with a layer (0.05–1 m) of Laevitrigonia and shell fragments with pebbles and blocks (up to 0.4 x 0.1 m) eroded from the hard-ground. This is covered by a fine-grained quartz sandstone and the whole bed (0.25 m) has been burrowed by small Thalassinoides. Above is 0.25 m of v. fine sand (almost 100 per cent quartz) which is horizontally laminated, shows primary current lineation and is burrowed in places by Thalassinoides. Fallen blocks show the bored horizon sometimes covered directly by this sand and in these cases the sediment fills borings and empty moulds of aragonitic bivalves.

Diapiric intrusion and 'fissure eruption' of bioturbated shelly sand through the overlying fine sand took place at Pointe aux Oies. These structures have been discussed by Ager & Wallace (1966a & b, 1970) but the rôle of the hard-ground is not mentioned. It seems probable that upward flow was inevitable due to its presence. Diapiric movement may have been the only way of releasing overpressured pore waters from the shelly pebbly sands, due to the presence of low permeability very fine-grained sands above.

Above the diapiric horizon there is a thin layer of pebbles of vein quartz, chert, jasper, Carboniferous limestones and Jurassic rocks. The coral 'Isastrea oblonga' is present amongst these but none was seen in growth position by the present authors although recorded in the past. The matrix of the pebble bed consists of clay, silt and v. fine sand (10–25 per cent), with admixed well-rounded coarse sand and granules of quartz and chert. This pebbly, gritty, mixture forms a bed 0.4–0.5 m thick and is overlain by 1.0 m of grey silty clay with medium to coarse sand in places. This clay contains large 'planks' of lignite at the base and micrite nodules up to 1.0 m across at the top. The latter was regarded as algal by Ager & Wallace (1970) but microscopic study has revealed only the presence of vertical and radiating lozenge-shaped moulds up to 1 mm long, probably originally gypsum (c.f. West 1975), in a micrite matrix containing only rare ostracods and foraminifera. This clay is overlain by 0.45–0.5 m of soft fine sand capped by 0.25 m of algal limestone composed of desiccated laminations of micrite with scattered v. fine sand. A further 0.6 m of fine-medium soft sand overlies this, below the base of the main algal limestone, the Calcaire des Oies (see Part 2 h).

The lignitic clay in the Upper Grès des Oies becomes sander to the north (Fig. 3) and dies out within 50 m of the section just described, to be replaced by soft v. fine sand with 1 per cent glauconite containing Oysters, Exogyra and Camptonectes. The topmost 0.55 m below the Calcaire des Oies consists of quartz sand (60 per cent fine-grained), bioclasts of bivalves, gastropods, serpulids and echinoids (20–30 per cent, up to 2 mm), and intraclasts of quartzose micrite and micrite-coated bioclasts (10–20 per cent, up to 3 mm). The sandy facies continues northwards for at least 400 m where it is exposed in an area of Recent sand dunes. To the south, about 200 m from the above section with clay, the basal part contains 'planks' of lignite (0.2–0.3 m) in a lenticular bed of clay which passes up into argillaceous sand.

(ii) South of Wimereux

Near the Marine Biological Station (Fig. 1) the Upper Grès des Oies consists of up to 4 m of soft sand with north-dipping cross-bedding visible at the base and with concretions in the upper half. At Cap d'Alprech, south of Boulogne, these beds are again sands and sandstones with cross-bedding dipping to the north. In contrast to the sections to the north, no pebble beds or diapirs are known.
(iii) The Rochette Conglomerate (Table 1; Fig. 3.)

At Pointe de la Rochette, where the channel-like erosion exists, there is a conglomerate up to 2 m thick resting on the hard-ground and containing great eroded and bored blocks (up to 1·5 m across) from the cemented bed (Fig. 3). The conglomerate also contains pebbles of earlier Jurassic rocks (including Kimmeridge Clay) and Palaeozoic rocks such as red, white and pink quartz, Lower Carboniferous limestone and chert, Devonian psammmites, Silurian slates and Cambrian quartzites. There are also rolled Portlandian bivalves and gastropods, reptile bones and 'Isastrea', apparently in growth position. Above the conglomerate is at least 3 m of inaccessible cross-bedded sands and sandstones.

The Rochette Conglomerate is recorded in a quarry about 1 km south-east of Wimille where it is 2 m thick with the Lower Grès des Oies exposed below and sands above (Rigaux 1892). It is also visible in a road cutting on the N1 about 1 km south of Wimille where 1·5-1·6 m of pebbles are exposed, with current-deposited trilobids in the upper part. The conglomerate rests on 1·5+ m of hard shelly sandy limestone with ammonites. The top of the conglomerate is covered irregularly by red clay with ironstone known as 'Wealdien'. The conglomerate is not recorded in other sections at this level elsewhere in the region.

(g) The Calcaire des Oies (0·2-1·3 m; Fig. 3.)

The Grès des Oies is capped generally by algal limestones but in places there are beds with ostracods or beds composed almost entirely of the tiny bivalve *Eocallista socialis* (common in Dorset at the junction between the Portland and Purbeck Groups, Townsend 1975).

In the northern part of the outcrop, around Pointe aux Oies, the algal limestone is 0·9-1·3 m thick, resting on laminated or bioturbated calcareous sands of the Grès des Oies, although at one point (Fig. 3) it thins to only 0·2 m. The limestone is tufaceous, consisting of large circular concretionary masses identical to those of the basal beds of the Lulworth Formation in Dorset (Townson 1975, West 1975). The bulk of the Calcaire des Oies has been formed by the blue-green alga 'Spongiosstromata' (Pugh in Ager & Wallace 1966a) and consists of laterally-linked hemispheres (LLH) and concentric stacked hemispheres (SC-H) of Logan *et al.* (1964), as described by Pugh (1968) in Dorset. The topmost 0·1-0·15 m of the Calcaire des Oies often contains minute bivalves and pisolithic algal debris which rapidly grades up into grey and red clays of the 'Wealdien'.

South of Wimereux, near to the Marine Biological Station, the Calcaire des Oies consists of 0·5-1·0 m of limestone entirely composed of whole casts of *Eocallista*, forming a bivalve granule grainstone. A little further south, towards Pointe de la Crèche, the facies changes to lime mudstone (1·1 m) containing minute bivalves, with a 0·2 m clay bed in the middle (Fig. 3). The limestone contains 1 per cent quartz sand, bivalve fragments, indeterminate biochens, superficial ooids and possible shrinkage cracks.

Above Pointe de la Crèche, Rigaux (1865) recorded 1·8 m of limestone, 'concretionary' in the lower part, rich in *Eocallista* in the middle and fine-grained above. The only other locality lies just south of Cap d'Alprech where Rigaux (1865) recorded 1·4 m of fine-grained concretionary limestone with the base rich in ostracods and the top becoming laminated.

(h) 'Wealdien' (? 20-30 m; *fide* Arkell 1956)

Grey and red clays rest on the Calcaire des Oies, with an apparently transitional base. There is no marked break at this level despite the strange record of Bonte & Broquet (1962) of 'Wealdien' with a basal conglomerate containing green Albian sandstone, Chalk and Chalk flints. (At Le Fart the 'Wealdien' of Bonte & Broquet, 1962, does contain Chalk flint pebbles, according to Ager & Wallace, 1966b).

The clays immediately succeeding the Calcaire des Oies do not contain ostracods (*fide* Arkell 1956) but have a mixture of continental and marine macrofossils. See Part 3b(v).

'Wealdien' yellow sands with ironstone layers lie above and cut down through the grey and red clays as far as the Grès des Oies at Pointe aux Oies and near Cap d'Alprech (Ager & Wallace 1966a, Fig. 3) and even as far down as the Rochette Conglomerate near Wimille (pers. obsv.).

3. BIOSTRATIGRAPHY

(a) Ammonites and correlation with England

Ammonites are uncommon and often poorly preserved in the Boulonnais sections; museum collections are sparse and a lack of consistency exists in the literature when dealing with ammonite identification. Nevertheless, in the light of recent work on the Standard Portlandian Stage in England (Wimbledon 1974, Wim-bledon & Cope 1978) it is appropriate to review the ammonite stratigraphy of the Boulonnais sections and to make certain broad correlations with England.

(i) The age of the Tour de Croi Nodule Bed

This horizon, with its fauna of rolled phosphatised ammonites and other molluscs (see Part 3b(i)), has been interpreted in the past as the basal conglomerate of the Portlandian succession (*sensu anglico*), equivalent to the Upper Lydite Bed of the English South Midlands but supposedly covering a greater non-sequence (Rotunda
Zone to Albani Zone inclusive). Pruvost (1925) stated that some 130 ft. of the Dorset succession was not represented. This conclusion was followed by Arkell (1935) and Ager & Wallace (1966a & b). The accepted absence of the Albani Zone is, however, inconsistent with the ammonite records of Sauvage (1911), Dutertre (1925) or Pruvost & Pringle (1924), see Part 3a(iii).

The Tour de Croi Nodule Bed just north of Pointe de la Creche (Fig. 1) contains rolled Pectinatites and Pavlovia. In addition, fresh iridescent or Pruvost & Pringle (1924), see Part 3a(iii). ammonite records of Sauvage (1911), Dutertre (1925) of the Albani Zone is, however, inconsistent with the la Creche (Fig. 1) contains rolled Pectinatites and Pavlovia. In addition, fresh iridescent Pavlovia are present, which in their preservation are close to those of the Hartwell-Swindon Clay of the English South Midlands (Neaverson 1925). This suggests that the break represented by the bed is intra-Kimmeridgian, falling within the Pavlovia Zones and perhaps in part equivalent to the Lower Lydite Bed of the South Midlands (Arkell 1933).

(ii) The topmost Kimmeridgian Zone

This unnamed zone (soon to be described from the type locality in Dorset; Cope 1978) has yet to be identified in the Bas Boulonnais. If present it must lie in the Lower Assises de Croi. Assuming the Tour de Croi Nodule Bed is of Pavlovia pallasioides Zone age, then the Pavlovia rotunda and this new unnamed Zone must be extremely attenuated or absent.

(iii) The Progalbanites albani Zone

This earliest Portlandian zone is certainly present in the Bas Boulonnais section. Specimens of Epivirgatites, typical of the zone in Dorset, have recently been collected from the Middle Assises de Croi. Sauvage figured a similar individual in 1911 (pl. 9, Fig. 1); also, twenty four years before Arkell named the species, a specimen of Progalbanites albani (Arkell). Sauvage's assignment of these two species to the Lower Grès des Oies must, however, be incorrect (see Part v). The presence of Epivirgatites spp. and P. albani enables correlation of the Middle, and possibly some of the Lower Assises de Croi with at least part of the Massive Bed to Emmitt Hill Marls interval of the Portland Sand Formation of East Dorset (Townson 1975, Table 1). Thus, the Kimmeridgian-Portlandian boundary must lie in the lowest few metres of the Assises de Croi.

(iv) The Glaucolithites glaucolithus Zone

The hard micrite beds in the Upper Assise de Croi have recently (Wimbledon 1974) yielded fragments of body chambers readily assignable to the distinctive genus Glaucolithites and identical to material from Dorset and the Vale of Wardour in England. This does little more than prove the presence of the zone however, its precise limits are unknown. An unlikely mixture of forms has been recorded in the past, included 'Behemoth lapideus', Titanites pseudogigas and Kerberites, but none of these species in fact occurs in the Glaucolithus Zone assemblage (Wimbledon & Cope 1978). This is the first record of Glaucolithites from the Boulonnais and it permits correlation with at least part of the White Cementstone-Black Sandstone section of East Dorset (Corton Hill to Gad Cliff Members, Portland Sand Formation, Townson 1975, Table 1) and with the Upper Lydite Bed of the South Midlands (Wimbledon 1974).

(v) The Zone of Galbanites okusensis

No material has been collected during the recent study which can definitely be assigned to this zone. Numerous references in the literature to Crendonites gorei (Salfeld) and 'Behemoth lapideus' strongly suggest, however, that an Okusensis fauna is present. The name 'B. lapideus' seems to have been used for evolute forms within the Okusensis Zone fauna, including perhaps G. okusensis itself. The name C. gorei has been used indiscriminately in the past for any Crendonites species of the Okusensis or overlying Kerberus Zone.

The type specimen of C. gorei came (fide de Loriol & Pellat 1874–5) from the long-defunct quarries at Wimille (Fig. 1) which caused Pruvost (1925) to believe that it must have come from the Upper Assises de Croi. Both Sauvage (1911) and Dutertre (1925), however, confined the Gorei fauna to the Lower Grès des Oies but Pruvost (1925) considered that it ranged from the Upper Assises de Croi up into the Lower Grès des Oies. A complication to an understanding of the older accounts is the fact that Crendonites species were often confused with the inner whorls of the much larger Glaucolithites. It was this factor which, until recently, prevented recognition and definition of separate Glaucolithus and Okusensis Zones. The range of the Okusensis Zone in the Bas Boulonnais is at present unknown. The loss of the Wimille quarries is particularly unfortunate, because in their heyday they were clearly a good source of ammonites, presumably from both the Okusensis and Kerberus Zones.

(vi) The Zone of Galbanites kerberus

The characteristic coarsely-ribbed species of the Kerberus Zone in England, including certain Crendonites, have neither been found in situ in this study nor are previously recorded. However, other Kerberus Zone species are amongst the most common ammonites in the Boulonnais sections. Pruvost & Pringle (1924) erroneously placed Kerberites stratigraphically below 'Behemoth'. They stated that the Middle Grès des Oies contains Perispinctes bononiensis (de Loriol) and P. giganteus (Sowerby). Pruvost (1925) unfortunately later placed the occurrence of P. giganteus above that of P. bononiensis, following the then-accepted correlation of
the latter species with ammonites within the 'Cherty Beds' and the former with species in the overlying 'Freestones' of the Dorset 'Portland Stone'. In fact both these species, plus Kerberites and Crendonites spp., co-exist in the Basal Shell Bed on Portland and Arkell's Beds J-J' in the Isle of Purbeck (top of the Dungy Head Member, Portland Limestone Formation, Townson 1975).

Titanites giganteus (Sowerby) (recently redefined by Wimbledon & Cope 1978) and related species, persists in Dorset throughout most of overlying 'Cherty Beds' (Dancing Ledge Member, Townson 1975). It is these larger forms of the Kerberus Zone assemblage which are most common in the cliffs north and south of Wimereux. Titanites giganteus is present from approximately 2 m above the base of the Lower Grès des Oies to the top of the Middle Grès des Oies. Several specimens can be examined in situ on ledges formed by the hard cemented horizons south of the Marine Biological Station.

(vii) The Titanites anguiformis Zone

No ammonites of this, or younger, Portlandian zones have been found in the Bas Boulonnais. In fact, apart from a derived fragment mentioned by Dutertre (1925), no ammonites have been found at all above the top of the Middle Grès des Oies. The age of the Upper Grès des Oies, the Calcaires des Oies and the basal clays of the 'Wealdien' is unknown but it is likely that they were deposited during Kerberus and/or Anguiformis Zone times. This would be consistent with the situation in Buckinghamshire (Wimbledon 1974) and in certain boreholes in S.E. England (Townson 1971), where the change from ammonite-bearing to non-ammonite-bearing facies occurs immediately above beds with a Kerberus Zone fauna (W. A. Wimbledon; pers. obs.).

(b) Non-ammonite macrofauna and flora

Because the previous records of workers on the Boulonnais are so widely scattered it is considered useful to include the following compilation of macrofauna and flora, supplemented by personal observations. The terms 'common' and 'less common' are purely subjective, based on recurrence of observations. Unfortunately it has not been possible to assign records to the subdivisions of the Grès des Oies or Assises de Croi.

In terms of diversity the biota is similar to that of the Portlandian in England (Townson 1975 and references therein), given the fact that the descriptions are mainly limited to rare horizons with lithologies suitable for preservation. None of fossils listed is considered to be of use for time-correlation within the Portlandian.

(i) Tour de Croi Nodule Bed (Dutertre 1927)

Phosphatised:
- Anisocardia sp.
- Corbicella sp.
- Lithophaga sp.
- Lucina sp.
- Pleuromya tellina Agassiz
- Pleuromya sinuosa Roemer
- Corbula sp.
- 'Macrodon' Various trigoniids
- Protocardium morinicum de Loriol
- ‘Goniomya’ sp.
- ‘Cyprina portlandica’ ( = Eocallista sp?)
- Dicroloma sp.
- Ampullospira atheta d’Orbigny
- Pleurotomaria sp.
- Rhyynchonella sp.
- ‘Terebratula’ sp. (‘Zeilleria’)

Unphosphatised:
- Exogyra nana Sowerby
- Plagiostoma boloniensis de Loriol
- ‘Chlamys’ sp.
- Oxytoma octavia d’Orbigny
- Laevitrigonia sp.
- Protocardium morinicum de Loriol
- Ampullospira atheta d’Orbigny
- Rhyynchonella subvariabilis Davidson
- ‘Belemmites’ sp.
- Also various reptiles and fish bones, Crustacean remains, Cycads, ‘Sequoia’, Pinites, Pinus

(ii) Assises de Croi

Common:
- Myophorella sp.
- Laevitrigonia sp.
- Isognomon bouchardi Oppel
- Ostrea expansa Sowerby
- Ostrea dubiensis Contejean
- Camptonectes lamellosus Sowerby
- Plagiostoma rustica Sowerby
- Pleuromya tellina Agassiz
- Musculus autissiodorensis Cotteau
- Glomerula gordialis Schlotheim

Less common:
- Thracia sp.
- Oxytoma octavia d’Orbigny
- Buchia mosquensis Buch
- Protocardium morinicum de Loriol
- Plicatula boisdini de Loriol
- Panna constantini de Loriol
- Barbata cavata de Loriol
- Pholadomya rustica Phillips
- Anomia suprajurensis Buvignier
Astarte saemanni de Loriol
Eocallista implicata de Loriol
Mactromya veriotti Buvignier
Corbula bayana de Loriol
Natica athleta d'Orbigny
Pleurotomaria sp.
Nucleolites sp.
Pseudodiadema sp.
Cyphosoma sp.
Hemipedin bouchardi Wright
Hemicidaris sp.
Cidaris legavi Sauvage
Acroscala laenigemina de Loriol
Rhynchochella subvariabilis Davidson
'Terebratula' bononiensis Sauvage & Rigeaux
( = 'Zeilleria', ? = T. ovoides Sowerby? = Rouilleria Makridin?)
Discina latissima Sowerby
Lingula ovalis Sowerby

(iii) Grès des Oies

Common:
Laevitrigonia gibbosa Sowerby
Myophorella sp.
Protocardia dissimilis Sowerby
Plagiostoma rustic Sowerby
Camptonectes lamellosus Sowerby

Less common:
Eomiodon cuneatus Sowerby
Ostrea blakei Cox
Camptonectes suprajurensis Buvignier
Corbula autissiodorensis Cotteau
Isocardia letessoni de Loriol
Anomia suprajurensis Buvignier
Eodonax pellati de Loriol
Corbicella unionides de Loriol
Eocallista pulchella de Loriol
Cyrena pellati de Loriol
Mactromya verioti Buvignier
Musculus autissiodorensis Cotteau
Nucleolites sp.
Pseudodiadema thirrai Etallon
Cidaris florigemma Phillips
'Isastrea' (oblonga? Edwards & Haime)
Chenopus beaugrandi de Loriol
Procerithium leblanchi de Loriol
Procerithium manselli de Loriol
Procerithium pseudoeocavata de Loriol
Ampullospira ceras de Loriol
Natella elegans Sowerby
Natella pellati de Loriol
Nerita davidsoni de Loriol
Nerita sinuosa Morris
Nodeothenilla vivax Buvignier
Trochus mortieri de Loriol
Littorina bononiensis de Loriol

(iv) Calcaire des Oies

Eocallista socialis d'Orbigny
? Eocallista intermedia de Loriol

(v) 'Wealdien' (Dutertre 1925)

Ostrea, Mytillus, Corbula, Cyrena, Paludina, Cyclas, Unio.
Goniophis, Megalosaurus, Strophodus, Hybodus, Lepidotus, Pyenodus, Ischyodus, Iguanodon.

4. DEPOSITIONAL HISTORY

The late Kimmeridgian to end-Jurassic period is considered to have been a time of worldwide fall in sea level (Hallam 1969). In Dorset this is manifested by the vertical change from marine shales to silts, to carbonate mudstones and grainstones, to evaporitic non-marine deposits (Townson 1975, West 1975). Periods of relatively slow deposition have been recognised in Dorset but subsidence was generally continuous. In the marginal areas however, such as the South Midlands and the Bas Boulonnais, the succession is thinner, with evidence that sedimentation varied from rapid to slow or even ceased at times. Deposition was dominated by terrigenous supply and periods of erosion occurred.

The sequence in the Bas Boulonnais (Fig. 2) shows an overall shallowing with variation in rates of accumulation following the intra-late Kimmeridgian break at the base of the Tour de Croi Nodule Bed. Gritty phosphatic horizons occur above and below this level (Pruvost 1921) and, in view of the ammonite evidence, (Part 3a) the break in time represented by this particular horizon may not be particularly significant.

The Lower Assises de Croi were relatively rapidly deposited with little time for biological homogenisation of three silt-clay-lime mud cycles (similar to those of the Corton Hill Member at Gad Cliff, Dorset; Townson 1971, 1975). Subsidence and/or supply rate evidently slowed during deposition of the Middle Assises de Croi, witnessed by the high concentration of glauconite, presence of phosphate, heavy bioturbation and possible encrusted surfaces. The presence of coarse quartz sand and chert granules ('lydites') indicates proximity of supply but glauconite and Rhizocorallium suggest generally low energy middle neritic conditions (Porrenga 1967, Ager & Wallace 1970).

Shallowing continued during deposition of the Upper Assises de Croi, as indicated by the presence of large Thalassinoides (Ager & Wallace 1970) and the low glauconite content. The supply of coarse clastics was reduced, however. Deposition of lime mud was common and a diverse echinoid-bivalve fauna flourished prob-
ably in generally medium to low energy inner to middle neritic conditions.

The Lower and Middle Grès des Oies are medium and high energy inner neritic sands, as indicated by their grain size, sorting, cross-bedding, diverse bivalve-gastropod-ammonite fauna and bioturbation. The contact with the Upper Grès des Oies is an erosion surface locally cutting deep into the Middle and Lower Grès des Oies (Fig. 3).

The Upper Grès des Oies was deposited by the following sequence of events:

(i) Downcutting of a relatively firm substrate in an estuarine/tidal channel at Pointe de la Rochette and inland (Figs. 1 & 3, angle with coastline unknown). Concordant lateral erosion of the Middle Grès des Oies probably also occurred, possibly to a considerable extent. The gap in time at this level is unknown and it is possible that a substantial thickness of strata was deposited and eroded.

(ii) Deposition of fine shelly sand in sub- to intertidal (beach?) conditions with a marine/euryhaline fauna.

(iii) Continued regression resulted in exposure to vadose conditions. This is indicated by solution of aragonitic skeletons and possible cementation of the hard-ground (deposition of ferrous calcite under phreatic reducing conditions was probably a much later unrelated phenomenon).

(iv) Subsequent transgression resulted in sub- to intertidal boring (or renewed boring) and erosion of blocks and pebbles of the hard-ground. Incorporation of a marine fauna resulted in a conglomeratic shelly sand. Moulds of aragonitic skeletons were filled with fine sand.

It is suggested that at this time a subtidal to subaerial pebble beach (cf. Chesil Beach, Dorset; Carr & Blackley 1974) migrated southwards and filled the tidal channel previously cut into the Middle Grès des Oies. This would account for: (a) the presence of a layer of exotic pebbles at Pointe aux Oies which pass southwards into the thick Rochette conglomerate; (b) the apparent absence of pebbles south of Wimereux (Fig. 1); (c) the presence of the marine fauna in the Rochette conglomerate. The diapirism and 'fissure eruption' at Pointe aux Oies to the north accompanied this increase in water depth.

(v) Shallowing recommenced with the deposition of cross-bedded, calcareous, fine to coarse quartz sands and lignitic clays. The rapidly laterally-varying facies, the euryhaline to marine fauna, the presence of only small Thalassinoides and the absence of ammonites suggests deposition in coastal lagoons/tidal swamp/intertidal sand beach conditions in close association.

The thin Calcaire des Oies was deposited under hyper- to hypsaline coastal lagoonal conditions during a brief absence of terrigenous influx. The southward change in facies (Part 2g, Fig. 3) may indicate a shallowing in that direction. The transitional change to continental conditions was completed by deposition of 'Wealdien' red and grey clays in a lacustrine/hypsaline lagoonal environment.

5. DISCUSSION

The abandonment of the Purbeckian 'stage' and the division of the post-Kimmeridgian Jurassic into nine Portlandian ammonite zones (Wimbledon & Cope 1978) means that the Portlandian of S.E. England and northern France now includes the non-marine strata. In Dorset the lowest six zones are present in marine facies, whereas in the Boulonnais only the lowest four are proven.

The 'Wealdien' of the Bas Boulonnais was found to be anomalous by Allen (1959) when compared with the Wealden of England and later Casey & Bristow (1964) proposed a 'Middle Purbeck' age. It is, however, reasonable to suggest that the 'Wealdien' clays correlate with the lower part of the Lulworth Formation of Dorset (Townson 1975). It is probable that it is the discordant ferruginous sands (Table 1, Fig. 3) which are 'Middle Purbeck' in age. They probably equate with the Whitchurch Sands—Cinder Bed 'event' in England, regarded as being basal Cretaceous (Casey 1963).

With regard to the better known marine Portlandian, it is over 165 years since the ammonite distribution in a measured section of Dorset was first described (Middleton 1812) but it has only recently been possible to make a credible, albeit imprecise, correlation with the strata in the Bas Boulonnais. Thus, the Tour de Croi Nodule Bed is now considered to be intra-Kimmeridgian and hence older than the Upper Lydite Bed of the South Midlands. The latter Bed is of Glaucolithus Zone age and thus approximately correlates with the Upper Assises de Croi. The change in deposition in Dorset from siliciclastics to marine dolomites (Townson 1974, 1975) also takes place during this Zone. The lithological boundary between the Assises de Croi and Grès des Oies appears to fall within the Okusensis Zone, as does the boundary between the Portland Sand Formation and the Portland Limestone Formation of Dorset. The break in deposition between the Middle and Upper Grès des Oies perhaps lies in the Kerberus Zone and thus may equate with the end of the middle regressive cycle in Dorset (Townson 1975).

The range of environments suggested for the deposition of the Upper Grès des Oies was recently examined by one of the authors in the State of Sabah (Malaysian Borneo). Clean beach sand, muddy tidal swamps, pebbly coastal streams, pebble beaches and tidal channels with basal lags of corals, marine bivalves, vertebrate
bones and wood were seen to exist within hundreds of metres of each other, bearing witness to the variety of conditions co-existing along a tropical coast backed by rapidly eroding hills of clastic sediments. Such must have been the conditions in the Bas Boulonnais during the mid-Portlandian, with fluctuations in rainfall and drainage pattern giving variations in supply of locally derived coarse clastics, probably under sub-tropical to tropical conditions.

Deposition of the marine Portlandian of the Vale of Wardour (Wimbledon 1976) and the South Midlands was also marginal to the basin and influenced by supply of terrigenous material but, in contrast with the Bas Boulonnais, these areas were bordered by land of lower relief. This in turn contrasts with the Dorset area, where supply of terrigenous material was virtually cut off during deposition of the Portland Limestone Formation on a swell away from the basin margin (Townson 1975, 1976).

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